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A Comparative Nutritional Life Cycle Assessment of Processed and Unprocessed Soy-Based Meat and Milk Alternatives Including Protein Quality Adjustment

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Combined nutritional and environmental assessment of foods and diets (III)

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Background

- Food system and especially animal-based products are associated to large environmental impacts
- One popular mitigation approach → replacement with alternative products
- Raises several questions:
  - Are they suitable replacements in terms of nutrient content and nutritional quality?
  - Can they fulfil the same function as the original?
  - How do they perform environmentally related to their function?
  - Is processing beneficial or not?

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Nutritional Life Cycle Assessment

Goal	Functional unit
Compare the environmental impacts of soy-based alternatives to their references considering the nutritional quality and nutrient density	• g qc-protein • NRprot7
Scope	**Impact assessment**
• Agricultural production and processing in Switzerland • Cradle-to-gate	• SALCA v2.01[1] • CED, GW, WS, LO, AT, EF

[1] Douziech et al. (2024) doi.org/10.34776/as183e

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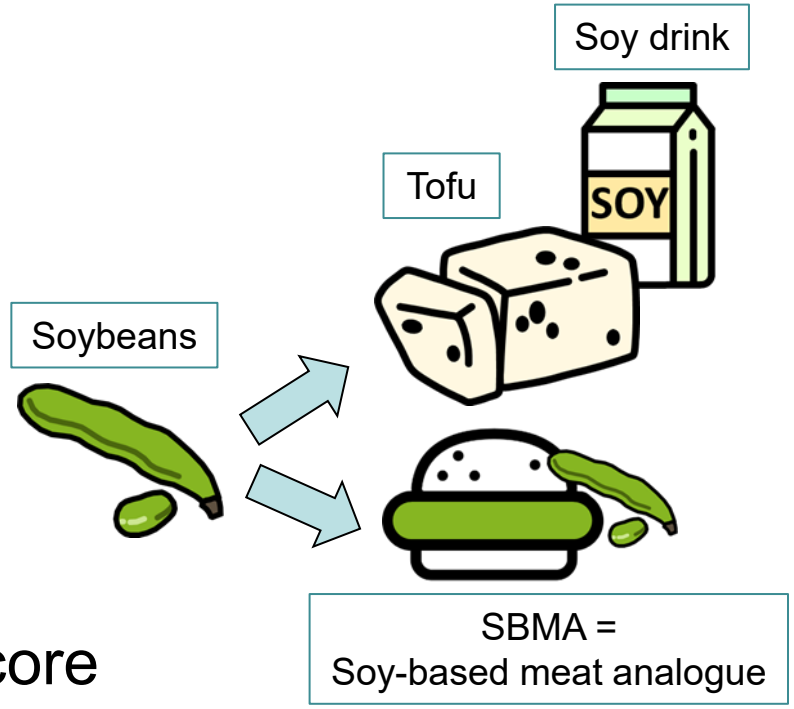
Quality of Plant Proteins

- Often lower than that of animal proteins
- Can be improved by combining different sources
- Processing may alter digestibility
- Influence on the function as protein sources
- How can the protein quality be quantified?
  - DIAAS - Digestible Indispensable Amino Acid Score

    → Amino Acid content and digestibility
  - Method for *in vitro* analysis[1]



$$DIAAS = \frac{\text{mg of limiting indispensable amino acid in the dietary protein}}{\text{mg of the same amino acid in the reference protein (usually egg protein)}} \times 100$$

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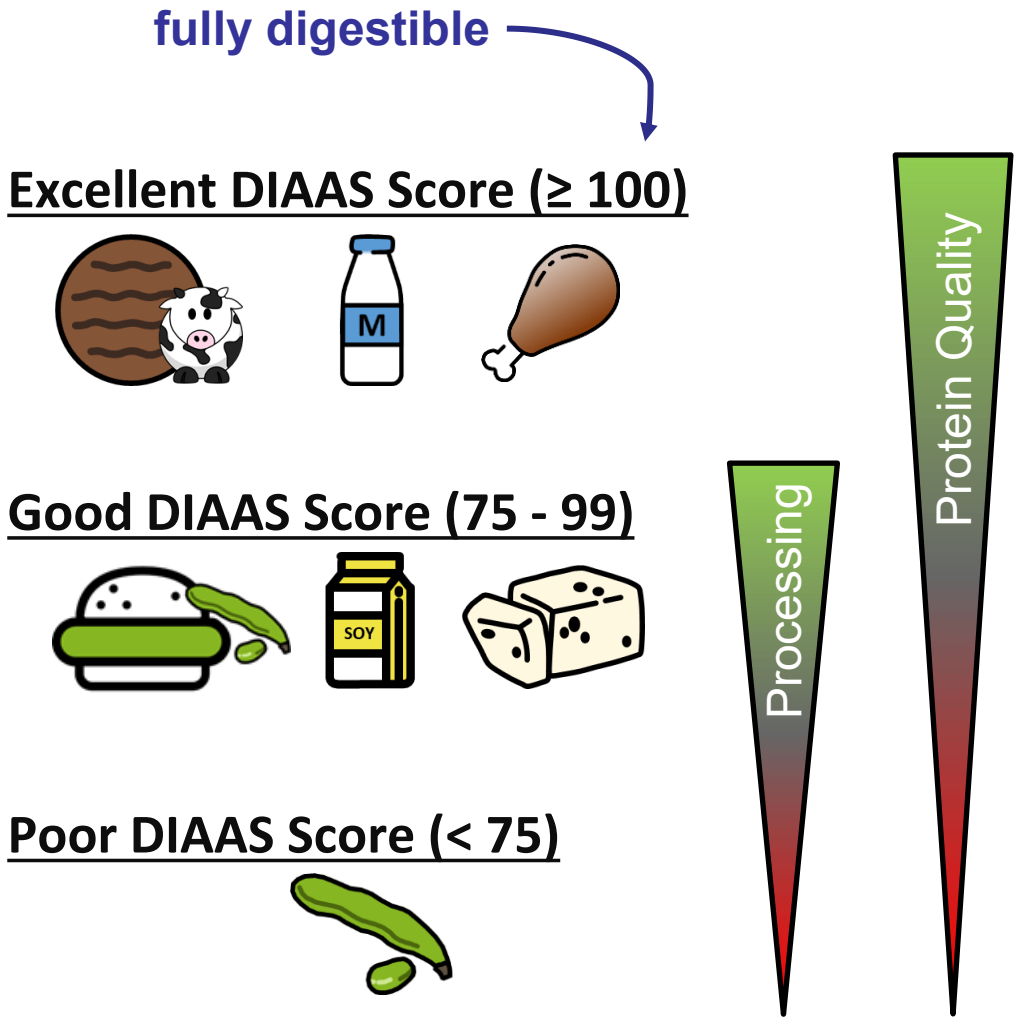
[1] Sousa et al. (2023) doi.org/10.1016/j.foodchem.2022.134720

Protein Quality

Table 1: The *in vitro* DIAAS values. Limiting amino acids in parentheses. The corresponding **qc-protein** is calculated by multiplying the protein content with the DIAAS.

Food item	Protein content [g/100g]	DIAAS [%]	qc-protein [g/100g]
Soybeans, cooked	16.3	51 (Trp)	**8.3**
Tofu, plain, fresh	14.4	84 (SAA)	**12.0**
SBMA, grilled	13.9	94 (SAA)	**13.0**
Beef, minced, grilled	32.6	124	**40.6**
Chicken breast, grilled	30.1	113	**34.0**
Soy drink, UHT	2.6	85 (SAA)	**2.2**
Cow milk, 3.5%, UHT	3.3	121	**4.0**

DIAAS = Digestible Indispensable Amino Acid Score
SAA = Sulphur-containing amino acids (Methionine, Cysteine)
Trp = Tryptophan



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Nutrient Density

- Consider the nutrient content as an index → **NRF7.2** (nutrient rich food) index
- Based on content of qualifying and disqualifying nutrients
- Related to Dietary Reference Intake (DRI) and normalised to energy content
- Adjusted to protein-rich foods (Green et al., 2023) → **NRprot7** & **LIM2**

  - Protein
  - Dietary fibers
  - Unsaturated fatty acids
  - Calcium
  - Iron
  - Zinc
  - Vitamin B12
  - Sodium
  - Saturated fatty acids

$$NRprot7 = \left(\sum_{i=1}^{i=7} \frac{nutrient_i}{DRI_i}\right) \times \frac{2000\ kcal}{E_j}$$

$$LIM2 = \left(\sum_{i=1}^{i=2} \frac{nutrient_i}{DRI_i}\right) \times \frac{2000\ kcal}{E_j}$$

$$where: i = nutrient, j = food\ item$$

DRI = Dietary Reference Intake; E = Energy

$$NRF7.2 = (NRprot7 - LIM2) * 100$$

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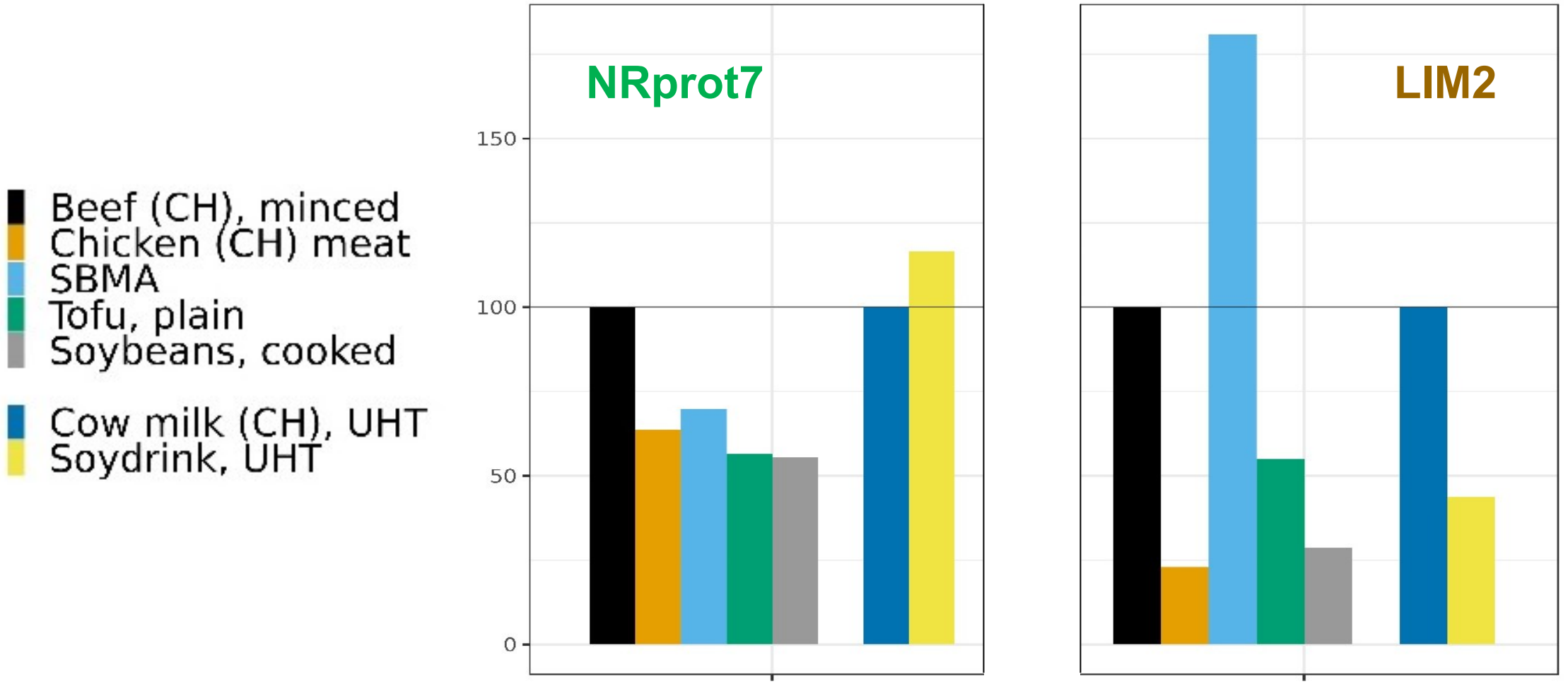
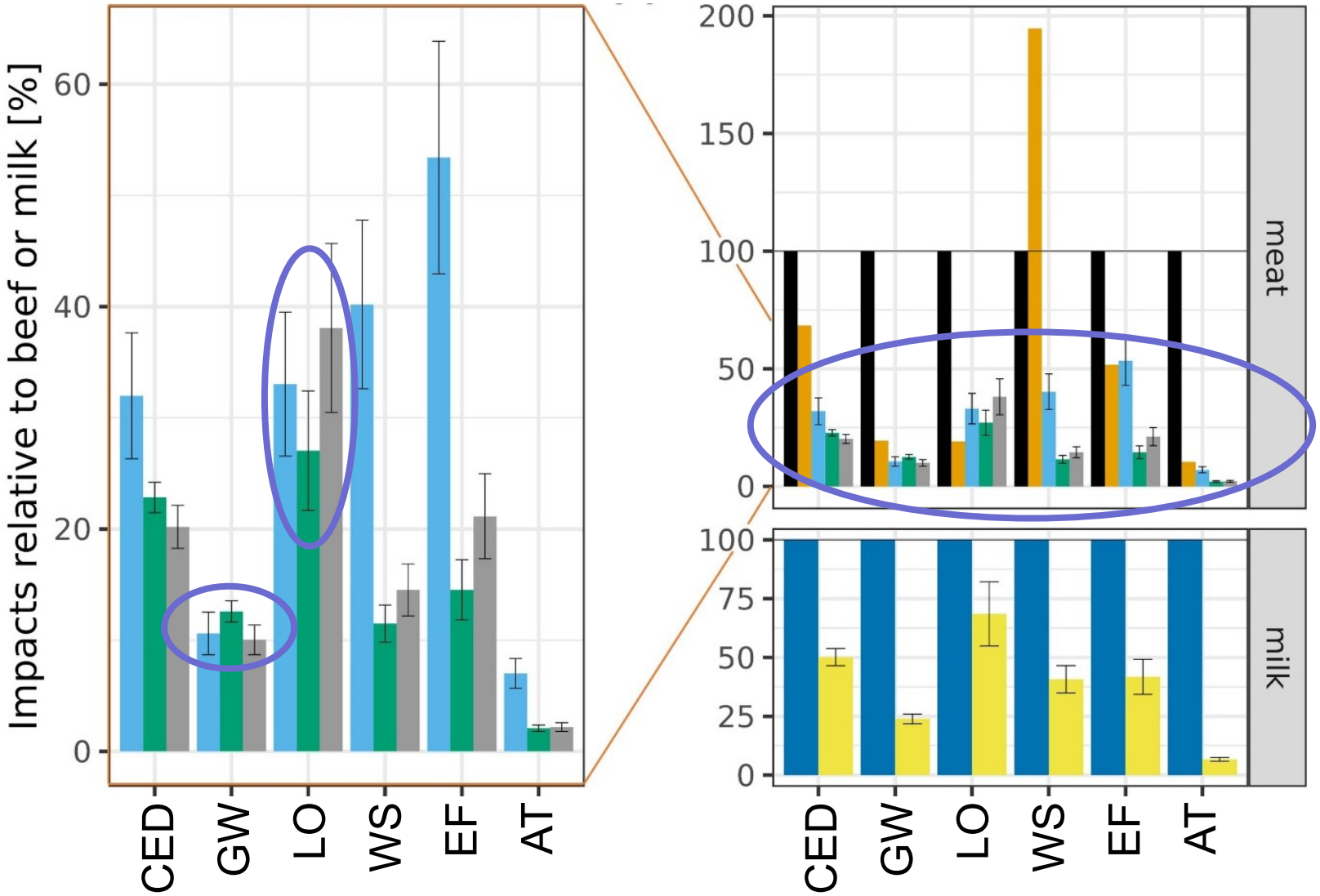
Nutrient Density - Comparison of the **NRprot7** and **LIM2** sub-scores relative to beef and cow milk [%]



Results



Comparison between alternative and reference products per **[g qc-protein]**. Range bars represent the sensitivity analysis.

- Beef (CH), minced
- Chicken (CH) meat
- SBMA
- Tofu, plain
- Soybeans, cooked
- Cow milk (CH), UHT
- Soydrink, UHT

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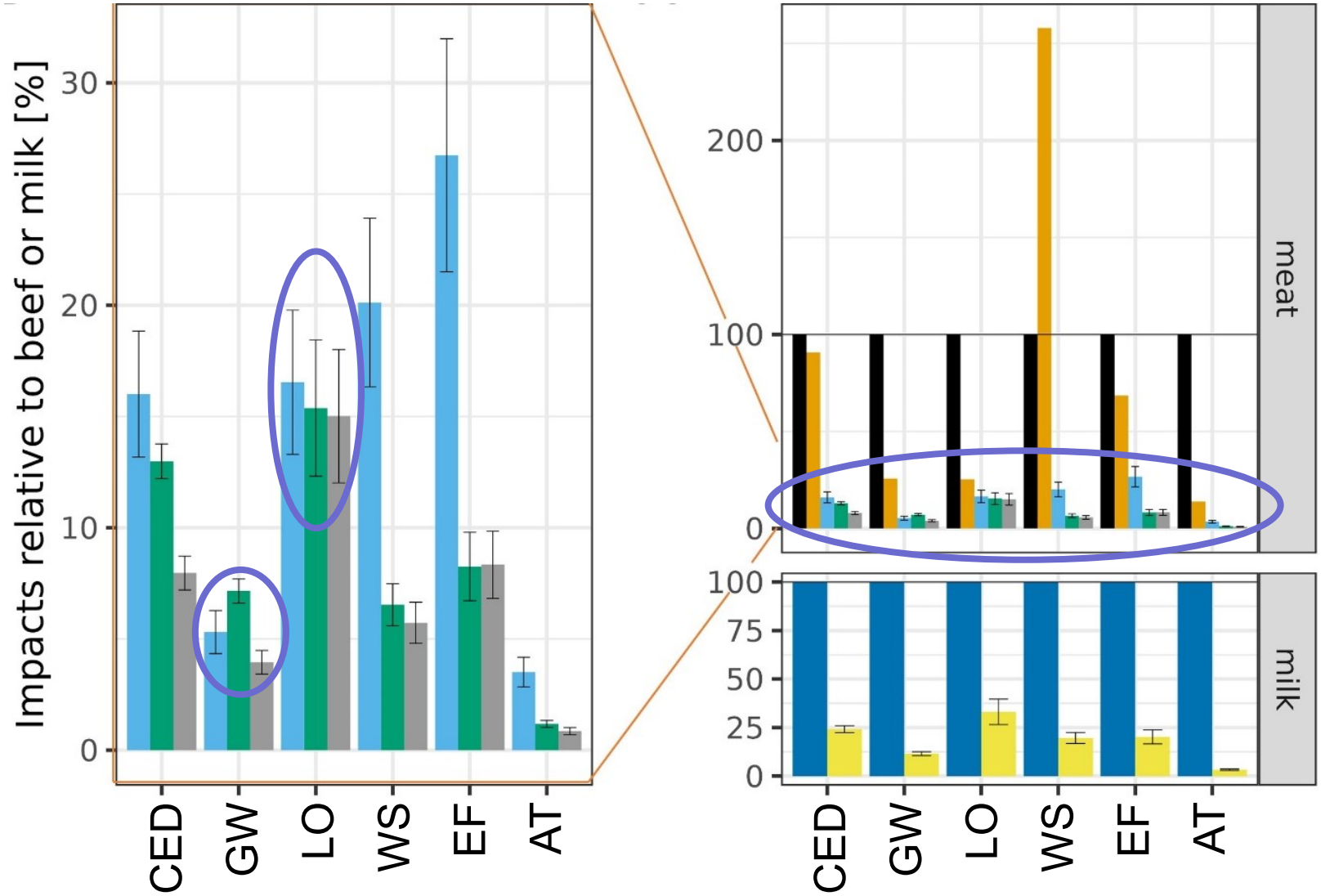

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Discussion

- Soy-based meat and milk alternatives **can contribute** to **lowering** the environmental footprint of nutrition
- High levels of **disqualifying nutrients** in processed soy-based alternatives **require** careful food **(re)formulation**, including micronutrient supplementation
- When nutritional functional units are used, **nutritional quality** adjustments are **relevant**

Take Home Message

- The n-LCA showed that the environmental impact of all soy-based alternatives was **4–20 times** lower than that of beef or cow milk.

- The higher protein quality and quantity of the processed SBMA compared to unprocessed soy-based alternatives were **not sufficient to offset its higher environmental impact** in this case study.

- Fostering standardization in nutritional LCA methodologies is crucial to ensure **consistent, reliable, and comparable results** across studies.

- Publication of the study available at:
  Herrmann et al. (2024) doi.org/10.3389/fsufs.2024.1413802
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Thank you for your attention!

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